Navigation Plan: Earth to Moon

Team name:

We thought Terrigena is the most appropriate name for our team because this is the Latin word for „created out of earth" („earthborn") and it reflects our most essential quality: we were born on Earth and we represent our planet. It also represents the bond between us all, because even if we have different parents, different skin colours and different opinions we are all „terrigenae". Also, it is a very special name to us, because it is a Latin noun, and our heritage is daco-roman.

Spacecraft name:

We chose Bendis because this was the ancient daco-tracic goddess of Moon. We thought the name Bendis represents best our ancient cultural and historical heritage (daco-roman) and it also suitable for a spacecraft that will reach the Moon.

Launch time and date:

After researching we discovered that on the 21st of July 2009 at 8:17 pm GMT the Moon is at perigee (it is closest to the Earth), at 357464 km from Earth. We consider the trajectory to be circular and not elliptical, and therefore we estimate the distance between the Moon and the Earth at 357464 km.

Because of this minimum distance, we choose the launch date to be the 21st of July.

Duration of journey:

We want to calculate the duration of the journey more accurately, and by researching we found the formula for determining how long it takes for a satellite to be transferred from the low Earth's orbit to the low Lunar orbit.(we considered the Lunar trajectory circular, and not elliptical to simplify a little the mathematical part of the task.)

The duration of the journey is: $\Delta t = \frac{\Pi}{2}(R - R1)\sqrt{\frac{R - R1}{2kM}}$

Where R is the distance from Earth to Moon and R1 is the radius of Earth's low orbit.

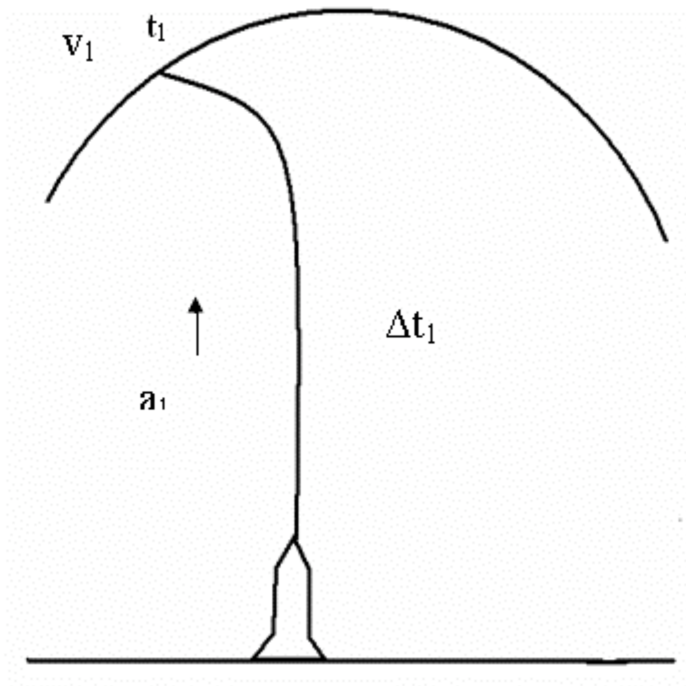
By calculating, we found out that the LCROSS-module will reach the low lunar orbit in 3 and half days.

Expected impact date:

The 24th of July.

Description of route and orbital paths:

Lift off. Entering the orbit

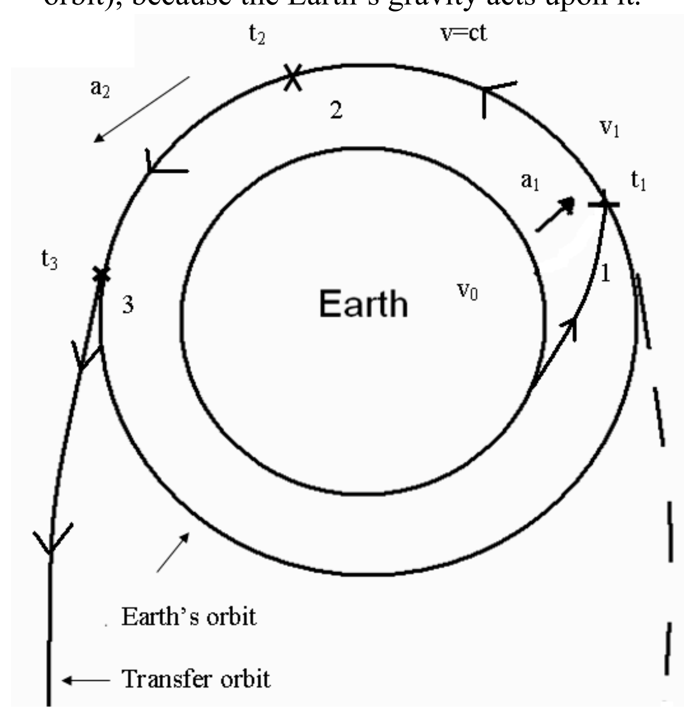


t1=the moment of time when the rocket enters the low-Earth orbit
v1=the first cosmic speed (this is the speed the rocket needs to have at t1, to enter low-Earth's orbit); the speed the rocket has when entering low-Earth's orbit

The rocket rises accelerating along the trajectory d_1 (the curve is given by the Earth's gravitation) until it enters the Earth's orbit.

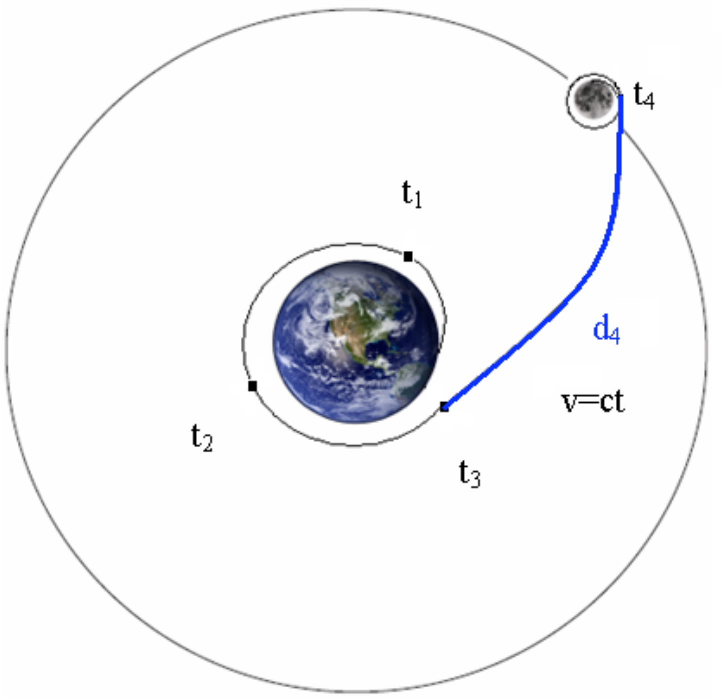
The rocket moves along the trajectory d_2 with the speed v_1 as soon as the engines are stopped, because of the Principle of Inertia, according to which objects tend to maintain their uniform and rectilinear movement as long as other objects/forces do not act upon them, changing this state. In space friction doesn't exist so the rocket will keep its speed v_1 from the moment when the engines are stopped. The rocket's trajectory is curvilinear (the Earth's orbit), because the Earth's gravity acts upon it.

1. Stopping the engines after lift off
2. Starting the engines in order to leave the Earth's orbit
3. Stopping the engines after leaving the Earth's orbit



The rocket will move accelerating along the trajectory d_3, from the time t_2 when the rocket starts its engines again until the time t_3 when they are stopped, in order to have enough force to leave the Earth's orbit using inertia at the time t_3 and to enter the transfer orbit with the speed v_3.

The rocket will move with the constant speed v_3 along the trajectory d_4, from the time t_3, when the engines are stopped, until the moment t_4, because it will not encounter friction and according to the Principle of Inertia, it will keep this speed. The rocket will not keep its rectilinear trajectory because of the Sun’s gravity. It will have a curvilinear orientation.

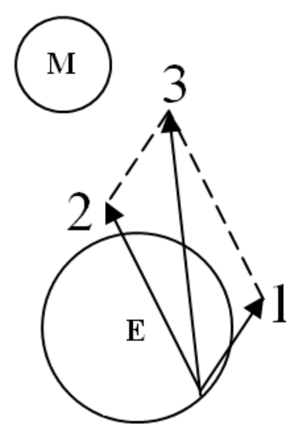


The rocket will fire its thrusters at the time t_4, to enter the Moon’s orbit. Because the Moon’s gravity is less powerful than the Earth’s, its orbit is smaller.

$$g_{Moon} = \frac{G_{Earth}}{6}$$

where *g=the distance between the low-lunar orbit and Moon’s surface* and
G=the distance between the low-Earth orbit and Earth’s surface

Once the Moon’s orbit is entered, the rocket will orbit until the time t_4 when it reaches the North Pole of the Moon. Here the thrusters will start in order to orientate the rocket towards the North Pole of the Moon.



The day and the time of the launch

1. *The direction the rocket tends to go on due to inertia*
2. *The direction the rocket tends to go due to the Sun’s gravity*
3. *The direction the rocket will finally go on, due to the compostion of forces*

The time of the launch: the moment when the distance between the Moon and the Earth is smallest (July 22^{nd}).
The time passed until entering the Moon’s orbit.
Arrival date: July 21st + Δt_f ($\Delta t_f = \Delta t$ which we calculated using the transfer orbit formula)

$$\Delta t_f = t_4 - t_0$$

$$\Delta t_f = \frac{\Delta t}{v\, m}$$

$$\Delta t_f = \Delta t_1 + \Delta t_2 + \Delta t_3 + \Delta t_4$$

$$\Delta t_f = \frac{d_1}{v_1 m} + \frac{d_2}{v_2} + \frac{d_3}{v_3 m} + \frac{d_4}{v_4} \qquad v_2 = v_1$$

$$\Delta t_f = \frac{d_1}{v_1 m} + \frac{d_2}{v_1} + \frac{d_3}{v_3 m} + \frac{d_3}{v_3} \qquad v_4 = v_3$$

On July 21st, the distance from the Earth to the Moon is 357464 km.

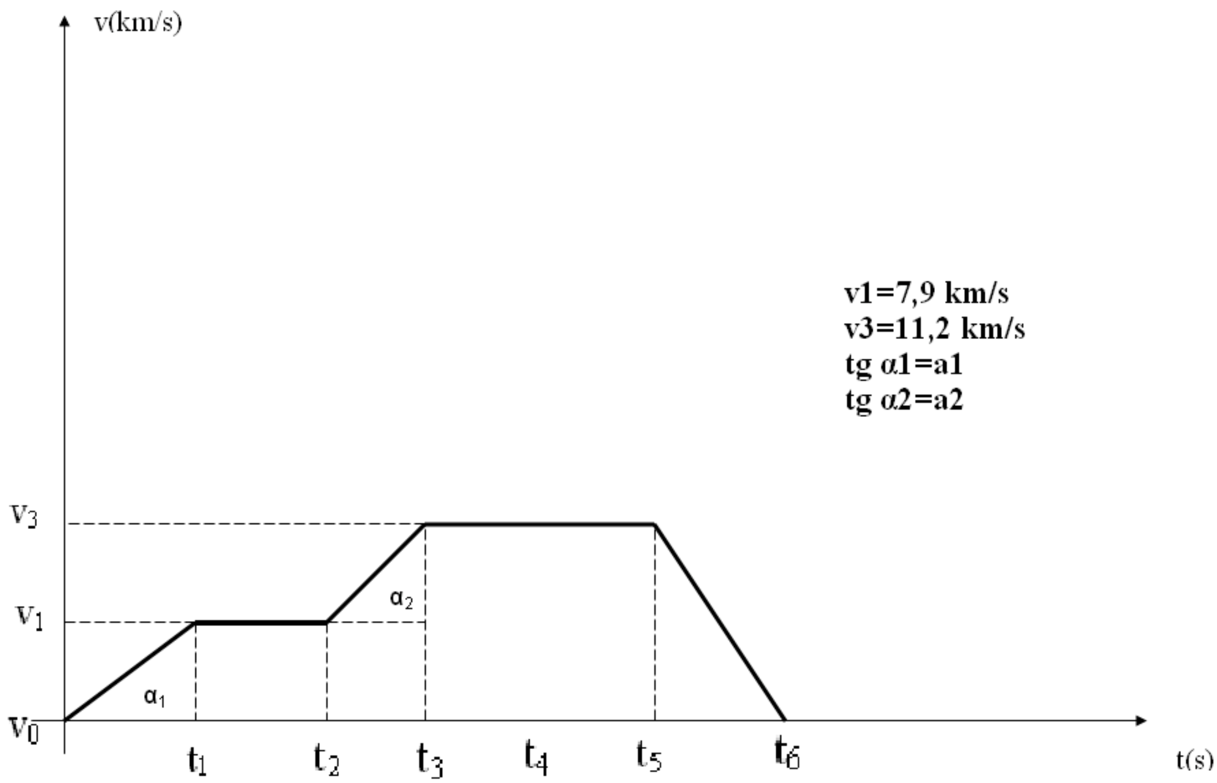
$x = v_l \cdot \Delta t_f$

$x = v_l\ (t_4 + t_0)$

v_l=3100km/h

Speed chart

Assuming that the speed at time t_4 is approximately equal to the speed at time t_3 and the adjustment time of t_4 is negligible compared to the other times => t_4 = the moment.



Navigation Instruments:

Because we cannot guide the LCROSS module from Earth we will use an Inertial Navigation System (INS). This will allow us to know the position, orientation and velocity of the spacecraft at any moment. We'll need the following instruments:

- Accelerometers measure the linear acceleration of the system in the inertial reference frame, which works on the same principle as the passenger that is pressed back into his seat as the acceleration increases and is pulled forward as the acceleration decreases.
- Gyroscopes measure the angular velocity of the system in the inertial reference frame.

We also thought that we might need a radar system, infrared radiometers, infrared lasers, charge-coupled devices, magnetospheric imaging instruments, polarimeters, photometers, plasma detectors, very long baseline interferometers, infrared lasers.

The advantages of the INS alone are huge: the INS requires initialization (it will be initialized before the launch), but after initialization, it doesn't require any more external data.

Methods of guidance, navigation, control, and tracking:

We thought about several guidance, navigation, control and tracking methods.

We found out that a navigation system is made out of three major sub-sections: inputs, processing, and outputs. The input section includes sensors, course data, radio and satellite links, and other information sources. First of all, we will use the INS as the input section, because it allows us to track the Bendis Spacecraft and it also measures the spacecraft's velocity, orientation and position.

Then there is the processing section, composed of one or more Central Processing Units, which integrates this data and determines what actions, if there are any, are necessary to maintain or achieve a proper direction in which the ship is moving. We thought that if we can't control the spacecraft from Earth we need to create a program that leads Bendis. On one hand, to create this kind of program we need very advanced technology that can measure everything up to the tiniest units of measuring: the INS. The program must detect if something goes wrong with the spacecraft, by correlating the data provided by the INS with Bendis' trajectory map. It will have all the situations where something went wrong with the spacecraft and its trajectory in its memory, implemented by the programmer.

Then, using the data provided by the INS and the information stored in its memory, it will be able to calculate which threshers to fire or how to modify Bendis' speed, in order to place the spacecraft on its right trajectory.

The information is then transmitted to the outputs which fire the proper engines and modifies the spacecraft's course according to the information received from the CPU.

Also, we thought that it might be useful if the spacecraft had all kinds of sensitive sensors to heat, light, speed of air, volume of gas etc.